Chapter 15 Overview of Biodiversity Loss in South America: A Landscape Perspective for Sustainable Forest Management and Conservation in Temperate Forests

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Abstract

South American forests contain a large fraction of the world's biodiversity, but it is obvious that if current trends of deforestation continue unchanged over the next decades, native forests will decline to an unacceptable levels. A landscape perspective to sustainable forest management and conservation provides a holistic framework to build up future research and tools towards an adaptive forest management approach to preserve forest biodiversity value while promoting the sustainable use of these forests. In this chapter we stress the importance of a landscape ecology perspective towards managing forests. We focus mainly on the temperate forests of Argentina and Chile, but within a broader framework of other forests in the South American region. An overview of threats to native forests is presented, and then new perspectives of conservation and management alternatives are analyzed. Our aim is to provide specific examples where a landscape ecology holistic approach contributes to integrating biodiversity value with the need for forestry activities, and provide insights into forest conservation and management initiatives, comparing traditional and timber-oriented management with new emerging approaches, including contributions of a landscape ecology perspective.

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15.1 Introduction

Biological diversity encompasses the variety of existing life forms, the ecological roles they perform and the genetic diversity they contain (FAO 1989). In forests, biological diversity allows ecological communities to adapt continuously to dynamically evolving environmental conditions, to maintain the potential for tree breeding and improvement (to meet human needs for goods and services and changing end-users requirements), and to support their ecosystem functions. Forest systems are impacted by multiple uses and influenced by global drivers. The multiple-use character of forests means that many different and sometimes conflicting goals exist regarding their management. Wide-ranging effects on the condition of forest ecosystems and their services are to be expected based on factors such as global market changes, increasing per capita income, demographic change, changes in consumption patterns, urbanization, globalization of the economy and new technology. Climate change will influence forest ecosystems around the world and the chain of causality is currently difficult to understand. Projected changes in the climatic system will affect natural and social systems globally, increasing their vulnerability and affecting their ability to supply goods and services to meet an ever increasing demand. For forestry and other natural resources management, the major challenges are in developing best practices for adaptive measures to maintain ecosystem resilience, and to reduce their vulnerability under various climate change scenarios.

While timber production often dominates the way in which forests were managed in the 20th century, new pressures in the 21st century drive a more balanced approach, calling for delivery of multiple goods and services. The process towards sustainable forest management is now considered consistent with the conservation of biological diversity. The values derived from biological diversity are associated with different scales that require different assessment methodologies. These methods included ecosystems, landscapes, species, populations, individuals and genes. Varying and complex interactions exist among all these levels.

We stress within this chapter the importance of a landscape ecology perspective towards managing forests. Forest management at landscape level is a complex practice of understanding the critical patterns of the landscape and their reciprocal interrelationship through the processes. Managing forests at a landscape level implies focusing on mosaics of patches and long-term changes in these mosaics to integrate ecological values (e.g. the maintenance of forest ecosystem health and biodiversity conservation) with economic and social

purposes (e.g. timber and recreation). Within this framework in this chapter, we address the importance of native forests and particularly, the value of forest biodiversity for the temperate forests of the South America region. We provide insights into forest conservation and management initiatives with particular examples from Argentina and Chile, which present a commonality in the need for sustainable forest landscape management. Our aim is to provide key examples and synthesis where a landscape ecology holistic approach contributes to integrate biodiversity value at the same time as the needs for forestry activities.

15.1.1 Forests and drivers of change

Our environment is continuously undergoing change caused by a combination of social, economic and natural processes which operate at all scales from the local to the global. The Convention on Biological Diversity agreed in 1992, and more recently in the UN Millennium Ecosystem Assessment (Millennium Ecosystem Assessment 2005), put in evidence a growing international awareness in the importance of maintaining healthy ecosystems to preserve life as we know it today. The problems associated with managing changes are primarily associated with how to detect the patterns of changes and link them to processes such as forest fragmentation due to human economical activities and their pressures. The fact that vegetation is changing at a variety of spatial and temporal scales makes it essential that we take into account variability at one scale when trying to interpret it at another (Hobbs 1990). Within this context, continual alteration of the Earth's vegetation cover is perhaps the most ecologically significant human impact on the global environment, with particularly serious implications for habitat loss and the maintenance of biodiversity (Vitousek 1994).

Superimposed on natural patterns of vegetation changes, are pressures induced by human impacts. Therefore the knowledge of anthropogenic imprints in the landscape is crucial to understand the alterations in critical ecological processes. Integrating human activity into climate system models is one of the great challenges within Earth system models. Particularly, changes in land use and in vegetation cover through deforestation or reforestation, invasive species, and changes attributable to the manipulation of the natural fire regimes are among the key topics where integrative, landscape ecology approaches can make a difference in our ability to understand and manage forested landscapes. In many areas of the world, as in South America, the natural vegetation is being significantly impacted and fragmented by clearance for agriculture, cattle and harvesting, and is being markedly changed by those traditional management practices (Tucker et al. 1986; Woodwell et al. 1986; Saunders et al. 1987; Hall et al. 2002; Gea et al. 2004; Martinez Pastur et al. 2009).

Net forest area continued to decline in Central and South America (FAO 2007). The leading cause of deforestation is the conversion of forestland to agriculture. Within the region, the largest area loss is in South America, while the largest percentage loss of forest area is in Central America (FAO 2006a). The continuing high rates of conversion from forests to other land uses in many countries within the region is a matter of great concern to decision makers. A more recent human pressure that has an important impact on biodiversity loss is the increase in forest commercial plantations of non-native species throughout the region. In Chile, the National Decree Law 701-1974 has been the forest policy initiative that subsidised the development of commercial tree plantations, converting the industry as a leading export sector in this country. Afforestation and non-native species introduction is also encouraged by REED (Rural Energy Enterprise Development program) projects, with funding from the United Nations Foundation; this program regrettably is also a cause of native forests loss in the search for wood energy.

15.1.2 Forests and ecosystem services

Humans use ecosystems to obtain a wide range of goods and services, such as clean water, air, food, wood and fuel, in so doing they modify them (Lambin et al. 2001). If we focus on forests alone, the latest Forest Resource Assessment (FAO 2006b) indicated that the functions of forests globally included production (34.1%), protection of soil and water (9.3%), conservation of biodiversity (11.3%), social services (3.7%), multiple purposes (33.8%) and no or unknown function (7.8%). In other words, one third of the World's forests are used primarily for production of wood and non-wood forest products and more than 300 million ha of forests are designated for soil and water conservation. Ecosystem goods and services and their continued delivery are essential to our economic prosperity and well-being. Modification of ecosystems to enhance one service generally has come at a cost to other services. For instance human intervention has increased food and timber production although this has resulted in changes in other services such as water regulation and recreation activities. Since changes in the quantity or quality of various types of natural resources and ecosystem services have strong impact on human welfare and the competitiveness of an economy, comprehensive methods to measure and value biodiversity and ecosystem services are needed (Juutinen et al. 2008; Kallio et al. 2008).

An important reason for degradation of biodiversity and ecosystem services is that benefits of the ecosystem goods and services are not fully captured in the commercial markets or adequately quantified in terms comparable with economic services and manufactured capital. Therefore they are often ignored or given too little weight in policy making (Costanza et al. 1997). Decisions on the use of natural resources should be based on a comparison of the ex-

pected monetary value of the harvested products and the values associated with the ecosystem goods and services foregone as a result of harvesting in managed forests (Kallio et al. 2008). Forests in particular provide timber through well established markets, but the un-marketed benefits of forests include recreational activities, forest carbon sequestration, maintenance of biodiversity, climate regulation, protection against natural hazards and water quality. Some preliminary studies in Chile demonstrate that this approach is becoming an important tool for decision making regarding costs to conserve forest resources (Núñez et al. 2006; Lara et al. 2009).

Un-marketed benefits of forests are directly linked to biodiversity value and forest habitat quality, studies in biodiversity loss due to forest management in South America showed significant impacts on the overall biodiversity loss (Deferrari et al. 2001; Spagarino et al. 2001; Martínez Pastur et al. 2002; Ducid et al. 2005). However, when forest diversity assemblages were analyzed at the landscape level, only some insects groups (e.g. coleopterons and dipterans) were greatly affected (Lencinas et al. 2007, 2008). It was demonstrated that the application of adaptive forest management strategies is the key to integrate economic needs, societal values and biodiversity conservation priorities (Martínez Pastur et al. 2007, 2009; Lencinas et al. 2007, 2009).

15.1.3 An overview of biodiversity loss in South America

By any standard of measure, the Latin American and the Caribbean (LAC) region is the repository of some of the World's richest biodiversity, containing 40% of Earth's plant and animal species (Global Environment Outlook 2000). The region boasts important forest resources accounting for 22% of the world's forest area (FAO 2007). Nine of the 25 most biodiverse countries are located in the LAC region (Caldecott et al. 1994). Particularly, South America has one of the largest expanses of primary forest in the world, representing 45% of the total area of primary forest reported in the World (FAO 2007). These forests are also very diverse. For example, the forests of the northern Andes (Peru, Ecuador and Colombia) rank among Earth's most biologically rich ones, while, further south, Chile and Argentina share one of the largest single blocks of remaining temperate forest in the world (Dinerstein 1995; Myers et al. 2000). Although South America still maintains vast areas of intact tropical and temperate forest, the region's biodiversity is facing significant and growing threats, including increased rates of deforestation. The last Forest Resource Assessment (FAO 2006b) shows that South America suffered the largest net loss of forests from 2000 to 2005, where about 4.3 million ha yr^{-1} and carbon in forest biomass decreased from almost 100 Gt annually in 1990 to 90 Gt in 2005. Of the ten countries in the world with the largest annual net loss in forest area during 2000-2005, two are in South America: Brazil has the highest net change in forest area in the world during that period with a decrease of

>0.5% of its total forest area per year and Venezuela is the second in the list (FAO 2007).

15.2 The biological importance of the native temperate forests of South America

Chile and Argentina together harbour the largest temperate rainforest area in South America, and more than half of the temperate forests in the Southern Hemisphere (Donoso 1993). These forests are classified as temperate forests or temperate-rainforests because of their geographical location outside the tropics, and because they experience high rainfall and low temperatures in winter. Similar forests are found in Oceania (Australia, New Zealand and New Guinea) and the Pacific northwest in North America. Forests in South America are important as they store vast quantities of carbon that contribute to global climate regulation, flood control, water purification and soil nutrient cycling, as well as provide habitat for a high diversity of species that contribute to the genetic material for valuable new products and a foundation for the resilience of natural systems. As an example, the Chilean flora is estimated to consist of about 5.1 thousand species, more than 180 families and one thousand genera. More than 50% of the species are thought to be endemic (Marticorena 1990). Within Chile more than 60% of the total flora and the endemic species are concentrated in central Chile from about 29.0° to 43.5° S. Central Chile has been identified as one of the World's 25 biodiversity hotspots, which are areas that contain at least 1,500 endemic species of vascular plants (>0.5% of the World's total) and have lost at least 70% of the original habitat (Myers et al. 2000). In a recent review of the World's hotspots, the central Chile area was expanded and re-designated as the "Chilean Winter Rainfall —Valdivian Forests Biodiversity Hotspot". The native vegetation of this area is estimated to have declined from almost 400 thousand km^2 to less than 120 thousand km^2 (Myers et al. 2000).

The temperate rainforests of southern Chile and adjacent Argentinean Andes are the largest in South America and represent almost one third of the world's few remaining large tracts of relatively undisturbed temperate forests (WRI 2003). These rainforests contain unique species such as the monkey-puzzle (*Araucaria araucana*), which can live as long as 1,500 years, and alerce (*Fitzroya cupressoides*), one of the largest trees found in the Southern Hemisphere. Alerce has the second longest lifespan in the world, with some trees living more than 3,620 years (Lara and Villalba 1993). Owing to their special biodiversity assemblages, these forests provide important ecosystem services that are the basis for a range of economic activities, including water production (quantity and quality), aquaculture and sport fishing, and ecotourism (Lara et al. 2009).

15.3 Threats to native forests

The leading cause of deforestation in South America is the conversion of forestland to intensive agriculture and cattle grazing. As was mentioned also plantations are among the growing pressures, increasing at a rate of 1.6 % per year in Central and South America (FAO 2006b). Consequently, native forests are suffering from intensive pressures that are threatening biodiversity and persistence of the eco-regions in the short and long term. As a result of human-induced pressures on these native forests, habitat quality and biodiversity are being degraded or fragmented, and large areas of forest are being lost. In all, the region's biodiversity is facing significant and growing threats. Many forests have already passed a threshold beyond which recovery is impossible (Newton 2007). The present situation is rather distressing, and many people are calling for the protection of remaining forest areas. Although the rate of deforestation in South America is high, vast areas of intact tropical and temperate forest remain, and it is critical that conservation measures are targeted to such areas.

15.3.1 Changes and pressures: An example from southern Chile

Miles et al. (2007) provided an overview of the threats to the temperate forests of southern Chile, based on a survey of expert opinion. Principal threats currently include land cover change, browsing by livestock, logging/fuelwood extraction, habitat fragmentation, pollution, loss of keystone species, fires, and invasive species. In coming decades, other threats are expected to become increasingly important, including climate change and development of infrastructure (such as roads, pipelines and dams). The relative importance of these different threats varies between different parts of the region, but many areas are being subjected to multiple threats simultaneously. Another key issue is that many threats interact. For example, in southern Chile, Echevería et al. (2007) documented positive feedback between the effects of habitat fragmentation, intensity of browsing by livestock and harvesting of trees for timber. As forest fragments decline in area, they become more accessible to both people and livestock, progressively eliminating old-growth forest areas from the landscape. In another example, an increase in the frequency of fires has been a major factor in the decline of the native forests in Chile, with an average of 13.6 thousand ha yr^{-1} of native forests destroyed by fires over the past two decades (Lara et al. 2002, 2006). In the summer of 2001-2002, more than 10 thousand ha of *Araucaria araucana* forests were burnt in areas protected by the State (Echeverria 2002). These threats have produced a landscape in which native forests have become increasingly reduced in extent and fragmented (Echeverria et al. 2006). Fragmentation has a range of effects,

including an increased susceptibility to fire and invasion by invasive species, reduced pollination and restricted seed dispersal (Forman and Gordon 1986). All of these can lead to an increased risk of extinction of some threatened species (Bustamante and Castor 1998; Bennett 2003; Bustamante et al. 2003; Echeverria et al. 2007). Fragmentation is also one of the greatest threats to Chile's native fauna, particularly for the mammals and birds that need large areas of intact forest to survive (Cornelius et al. 2000; Vergara and Simonetti 2004). Fragmentation also affects the ability of native forests and native species to respond to changes associated with global warming and climate change. In Chile, it is predicted that climate change should have its greatest impact on the forests of central and southern regions, especially at their northern boundaries with other ecosystem types (IPCC 2007). The distribution of the different types of native forest is strongly related to temperature, rainfall, evapotranspiration rates, soil types and hydrology. Changes in these factors could make some parts of the areas currently occupied by native species unsuitable.

Originally, the historical temperate forest cover, in Chile, particularly the Valdivia Rainforest Ecoregion (36° to 48° S) (Fig. 15.1), is estimated to have covered up to 18.4 million ha (Lara et al. 1999). According to the last vegetation mapping and assessment of the current forest area (CONAF et al. 1999), the native forests now cover only 13.4 million ha, a decline of more than 40% (Table 15.1). It is also estimated that more than 84% of the remaining forests are concentrated between 40° and 56° S. In southern Chile, between 35° and 38° S, key areas of rich floristic diversity have experienced

Table 15.1 Areas of native forests in the Valdivia Ecoregion* in Chile (between 18° and 56° S).

Forest types	Original data year 1550 (ha)	National Assessment 1997 (ha)	Remaining portion (%)
Fitzroya cupressoides	615,100	280,364	46
Pilgerodendron uviferum	1,035,509	557,812	54
Araucaria araucana	504,332	264,109	52
Austrocedrus chilensis	102,375	40,637	40
Mediterranean *Nothofagus*	983,143	314,075	32
Nothofagus betuloides	796,311	814,828	102
Nothofagus rainforests	4,513,083	1,509,949	33
Dryland forests	1,370,561	39,924	3
Broadleaved evergreen	5,453,022	4,201,796	77
Nothofagus pumilio	2,860,106	2,141,806	75
Chilean Palm	2,541	0	0
Nothofagus antartica	185,389	167,335	90
Total	**18,421,473**	**10,332,545**	**56**

**An ecoregion is a geographically distinct assemblage of natural communities that share a large majority of species, dynamics and environmental conditions (CONAF et al. 1999).*

a particularly severe decline in diversity along with a decrease of continuous forest patches. Currently there are no intact forest patches greater than 5,000 ha. This decline has been particularly severe in the Coastal Cordillera (WRI 2003).

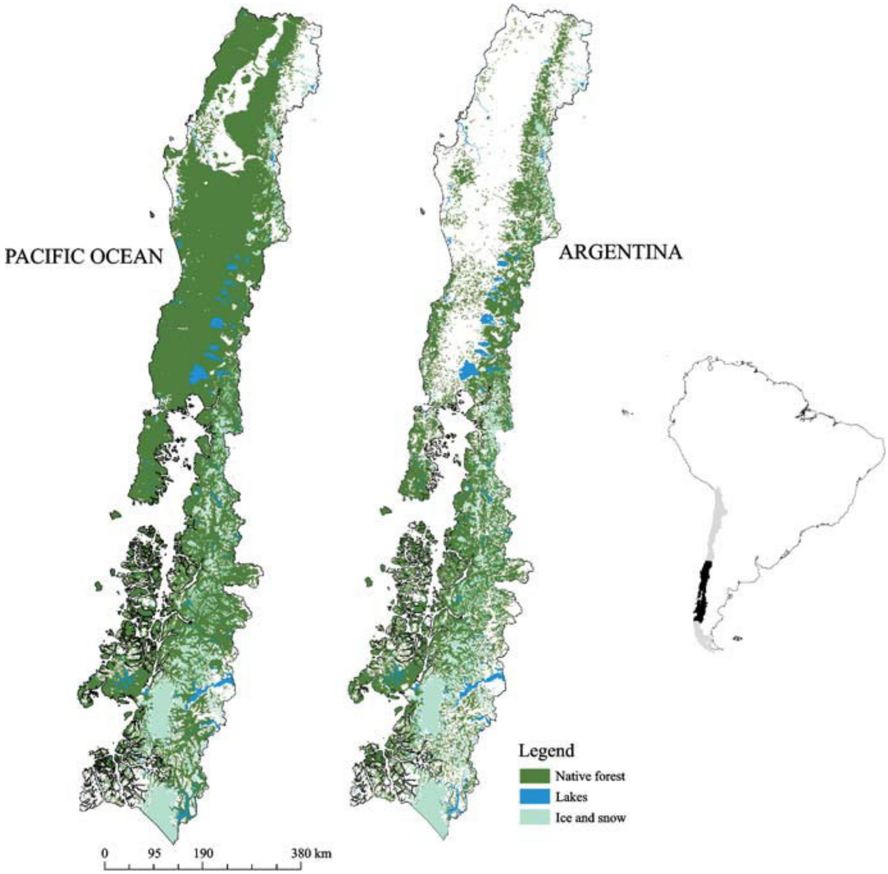

Fig. 15.1 Historical (1550-to the left) and current (1997-to the right) native forest cover, in the Valdivia Rainforest Ecoregion in southern Chile, between 35° and 38° S.

15.3.2 Changes and pressures: Examples from Argentina

In the case of Argentina, pressures on native forests are associated with the expansion of the agricultural frontier. Mainland Argentina covers a total area of 278.0 million ha with 41.5% in forested regions. Forest reserves protect several ecosystems (6.7 million ha) representing 5.8% of the total area. However,

these reserves are not equally distributed varying from 0.1% in the central-northern region to 34.6% in the Patagonian forests (Table 15.2). Argentina has 28.9 million ha of native forests (Dirección de Bosques 2004; UMSEF 2007) (Table 15.2, Fig. 15.2 and 15.3). Similar trends as seen in southern Chile have been documented in Argentina, where native forests have decreased from 37.5 million ha in 1930 to 28.9 million ha in 2007 (UMSEF 2007). Deforestation and forest degradation are associated with a number of threats, which again vary in importance in different forest regions (Table 15.2). In order of importance, principal threats include cattle production, agriculture, settlement, firewood extraction, exotic forest plantation, harvesting and fires. One classic example of rapid conversion of land cover/land use with important negative impacts on the local population and biodiversity can be found in northern Argentina, where environmental conditions have encouraged the development of extensive industrial agribusiness (e.g. soybean, sugar cane, cotton and cattle

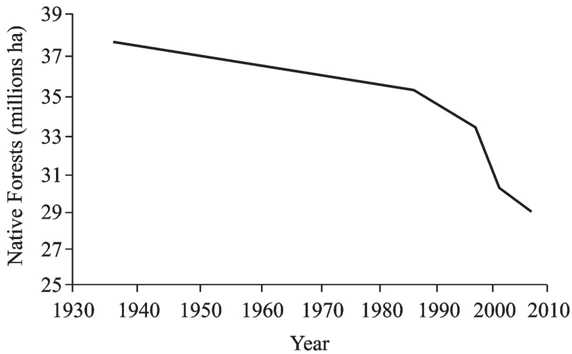

Fig. 15.2 Native forest rate loss in Argentina (1930-2007) (Dirección de Bosques 2004; Montenegro et al. 2005; UMSEF 2007).

Table 15.2 Main threats to native forests by region* in Argentina (0 = no pressure, 1 to 5 = pressure levels).

Forest Regions	Agriculture	Exotic plantation	Cattle production	Harvesting	Firewood extraction	Settlement	Fires
Selva Misionera	3	5	2	3	2	3	1
Selva Tucumano Boliviana	4	2	3	3	2	3	1
Parque Chaqueño	5	1	5	2	4	4	2
Espinal	5	3	5	1	5	5	4
Bosque Andino Patagónico	0	0	3	2	1	2	3

*For regions location see Fig. 15.3.

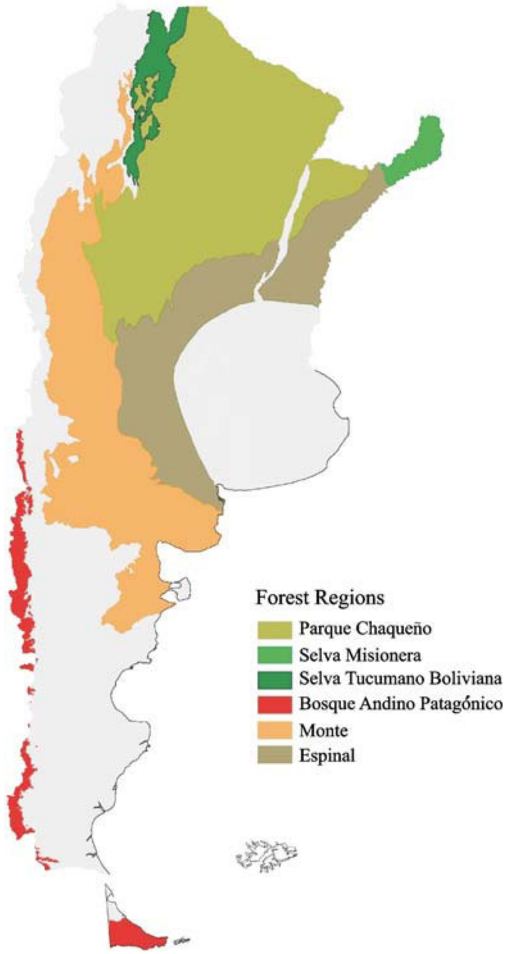

Fig. 15.3 Geographical location of native forest regions in Argentina (based on Dirección de Bosques 2004).

production). Furthermore, the development of agribusiness displaces local people who settle in forested areas, increasing the impacts through fuel-wood extraction and grazing livestock (cattle and goats) for family consumption.

In the south, in Patagonia, principal threats are due to human economical activities, such as cattle production, which impacts natural processes (e.g. forest succession and natural regeneration) and increases risks of forest fires. Many forest fires are intentionally set to increase the area of pastures or to allow the extraction of fuel-wood in places where live wood extraction is forbidden by law (e.g. Nahuel Huapi National Park).

Native forest harvesting in Argentina is mainly carried out in compliance with national and provincial law, but the lack of long-term forest policy leads

to an economical and ecological degradation of the native forests. The continuous pressures of clear cuts and wood extraction without silvicultural planning result in unsustainable forest management.

15.4 Forest management and conservation strategies: A response to native forests' threats

In addition to the government system of national parks and reserves in Chile, there are numerous reserves that are not included in the State protection system, ranging in size from several hectares to several hundred thousand hectares. Many of these reserves are owned by local or indigenous communities, small collectives of private individuals, wealthy individuals or Chilean NGOs such as CODEFF (Chile's Committee for the Defence of Flora and Fauna, an affiliate of Friends of the Earth). Most of these reserves have been linked to form the Network of Protected Areas in Chile [Red de Areas Protegidas Privadas (RAPP)]. In 2005, the RAPP network included 133 reserves covering a total of 386.5 thousand ha (CONAMA 2005). In some cases private reserves have been established to assure connectivity (e.g. corridors and stepping stones) between the existing National Parks and the Reserve network. More than 80% of protected land is located either in the Andes or in the southern regions.

The increasing number of reserves could be an important milestone for the conservation of some threatened habitats and species. For instance, the Pumalín Park, a privately owned land located in southern Chile, is focused on the sustainable use linked to conservation actions in collaboration with local communities, containing significant areas of old-growth forests of *Fitzroya cupressoides*. This park is an example of a private initiative to protect an area that was declared a Nature Sanctuary on August 19 of 2005 by the Chilean government, granting it additional environmental and undeveloped protection. The Conservation Land Trust (a U.S. environmental foundation) donated an important part of these protected lands to Fundación Pumalín (a Chilean foundation) for their administration and continual development as a type of National Park with public access to a privately held reserve. However, many other reserves are relatively small and have only been recently established so that their longevity and the success of their management are not assured. On the other hand, between 35° and 39° S, many of the remaining native forests with a great biodiversity value are owned either by forestry companies or by small landowners. In the coastal Cordillera of these regions, the remnant forests on land owned by forestry companies tend to consist of scattered fragments either along watercourses or on unusable land and are often surrounded by plantations of *Pinus radiata*, *Eucalyptus globulus* or by agricultural lands. These areas are vulnerable to the effects of human disturbances, especially fuel wood extraction. However, a limited amount of restoration work is being

undertaken on company lands. These companies are also developing codes of practice and management to obtain forest certification. This is a welcome development but the long-term commitment of these companies has yet to be tested and unless these areas are expanded, the biological viability of the smaller fragments remains uncertain.

In Argentina, forest reserves represent 5.8% of the total protected area, which encompasses 6.7 million ha of protected forest ecosystems (Table 15.3). However, these reserves are not equally distributed, varying from 0.1% in the Espinal region (northern Argentina) to 34.6% in the Patagonian forests (southern Argentina) (Table 15.3). These regions contain 28.9 million ha of native forests (Dirección de Bosques 2004; UMSEF 2007) (Table 15. 3).

Table 15.3 Forest reserves and native forest area by main forest Regions in Argentina (Dirección de Bosques 2004).

Forest Regions	Area	Reserves		Native Forests*	
	millions ha	millions ha	%	millions ha	%
Selva Misionera	3.01	0.49	16.1	1.45	48.3
Selva Tucumano Boliviana	5.48	1.50	27.3	3.73	68.0
Parque Chaqueño	67.50	2.46	3.6	23.37	34.6
Espinal	33.00	0.04	0.1	2.66	8.1
Bosque Andino Patagónico	6.45	2.23	34.6	1.99	30.8

15.4.1 Spatial conservation and prioritization approaches

Spatial conservation prioritization approaches, suitable for planning the expansion and connectivity of reserve networks constitutes one of the most successful conservation strategies to increase forest-protected areas (Margules and Pressey 2000; Pressey et al. 2007; Luque 2000; Luque and Vainikainen 2008). In 2005, globally, more than 400 million ha of forests, or 11% of the total forest area were designated for the conservation of biological diversity as the primary function. The area of forests devoted to conservation of biodiversity has increased by at least 96 million ha, or 32% since 1990. The latest trends show that in the last 15 years South America has one of the highest increases in conservation area in the World, from 70 million ha in 1990 to 92 million ha in 2005. However, declaring an area under a protection status is not enough. In order to preserve the future of forests, they need to be effectively managed to conserve the values for which they were created. Economic resources and technical capacity are limited and policy implementation is weak to implement a coherent plan for forest protection. Moreover, declaring forest-protected areas is not a viable option in most of the regions, as most of the land in the region is privately owned, and there is a need for income. Therefore, a viable conservation strategy in the region has to create corridors between forest-protected areas of different status. Viable areas for

species movement, flow of materials and genetic exchange have been created with this approach (Pacha et al. 2007; Armenteras et al. 2003; Bennett 2003).

Clearly, the expansion of the protected areas should be based on all available information and expert knowledge. In addition to this, it is desirable to employ quantitative decision support tools to aid the decision making. Such tools in the form of decision-theoretic and optimization techniques have been developed in conservation biology, under the rubric of systematic conservation planning and spatial conservation prioritization (Margules and Pressey 2000; Cabeza and Moilanen 2001; Sarkar et al. 2006; Pressey et al. 2007). Previously, a variety of conservation approaches and solution methods have been applied in the context of forest conservation, such as species richness extrapolation (O'Dea et al. 2006), species compositional similarity (Steinitz et al. 2005), gap analysis (Montigny and MacLean 2005), multiple use management planning (Baskent et al. 2008), simple heuristic algorithms (Virolainen et al. 2001; Heikkinen 2002), genetic algorithms (Hölzkamper et al. 2006), simulated annealing techniques (Boyland et al. 2004; Rayfield et al. 2008) and linear programming optimization (Ricker et al. 2007). More recent works have provided a novel spatial conservation prioritization approach suitable for planning the expansion of conservation area networks. This approach is based on high-resolution GIS data covering the planning area. The relevant planning criteria depend on spatial information related to forest quality, connectivity of forest types, and proximity to existing conservation areas (Luque and Vainikainen 2008). Forest inventory data and remote sensing techniques at the regional and/or national level are used for the purpose of constructing a biodiversity quality index, which together with a cost-effect analysis provides an overall indicator suitable for protection of forest biodiversity (Juutinen et al. 2008). Kallio et al. (2008) incorporated similar indices from the same data into a spatial partial equilibrium model simulating the forest sector for optimal regional allocation of forest conservation sites.

Another option, apart from the design of protected areas and corridors, is to promote sustainable forest consumption. This is the approach of the Forest Stewardship Council (FSC), a nongovernmental, non-profit organization that promotes the responsible management of the World's forests. Established in 1993 as a response to concerns over global deforestation, FSC is widely regarded as one of the most important initiatives of the last decade to promote responsible forest management worldwide. FSC is the fastest growing forest certification system in the world (FAO 2007). Products carrying the FSC label are independently certified to assure consumers coming from forests that are managed to meet the social, economic and ecological needs of present and future generations. More than 100 million ha forest worldwide were certified to FSC standards in April 2008, distributed over 79 countries (http://www.fsc.org/facts-figures.html).

15.5 Management solutions: Modeling dynamics of forest ecosystems

Sustainability of forest ecosystems affected by the use of forest-based resources requires an understanding of the links and balance between productivity, natural forest dynamics, soil processes and their interaction with natural and anthropogenic disturbances. During the recent three decades intensive studies have been done to develop forest ecosystem models (Levine et al. 1993; Tiktak and Van Grinsven 1995; Ågren and Bosatta 1996; Friend et al. 1997; Morris et al. 1997; Mäkipää et al. 1998; Chertov et al. 2003). Modeling has been used to analyse the impacts of different harvesting systems, natural forest disturbances, forest dynamics, climate change and carbon balance. Forest ecosystem models can effectively extend the classical approach where growth functions and tables are used for the prediction of the forest growth and soil nutrition in the changing environment under new silvicultural regimes. The level of the basic forest unit (e.g. stand as inventory compartment) can now be modelled well in relation to the problems of the stand's productivity in different climatic and site conditions. Moreover, there are combined models which are able to describe the biological turnover of the elements (e.g. carbon and nitrogen) in the soil-vegetation system (Chertov et al. 2001; Komarov et al. 2003). Forest ecosystem models with a multi-scale approach are needed to meet demands from policy makers and managers to predict the impacts of different scenarios of use and management of forest resources.

Forest management practices, site preparation and fertilisation are known to deteriorate surface and ground water quality due to increased leaching of nutrients and export of suspended solids. Even though the export of nutrients from forested areas is far less than that from agricultural lands, because forest management is implemented in such large areas, the total stress on water bodies can be significant. The nutrient export from forested catchments can be effectively decreased by water protection, e.g. by leaving untreated buffer zones between water body and the treated forest area (Ahtiainen and Huttunen 1999; Jacks and Norrström 2004), as recommended by present guidelines for forest management. This, however, excludes the buffer zone areas from the practical forestry and causes losses of trade incomes from the timber located in the buffer zone. On the other hand, the buffer zones can provide important associated services like game, berries, habitat for species that are stressed by the management and improve the water quality exported from the catchments areas. So far, there are few studies concerning the costs and benefits of the buffer zones.

15.5.1 Landscape ecology as a tool for forest management and conservation

To achieve sustainable forest management, tools for assessing the forest system as a whole are needed. Both the protection of the remaining native forest and a sustainable management of forest and forestry operations for the whole landscape are needed. In recent years, several studies demonstrate that management of forest ecosystems should not exclusively occur at a single scale (e.g. at stand level) (Spies et al. 2002) or based on a disciplinary research framework (Wu 2006). On the contrary, the hierarchical and pluralistic framework of landscape ecology (Forman and Gordon 1986; Naveh and Lieberman 1994) may substantially facilitate the management and conservation of native forests. In Argentina and Chile, only a few examples exist of managing forest resources under a multiscale and interdisciplinary approach in order to maintain and restore the goods and services produced (Meynard et al. 2007; Lara et al. 2009) and to conserve biodiversity (Geisse and Nelson 2005; Hechenleitner et al. 2005).

A landscape perspective is needed whenever landscape spatial patterns can be expected to have a significant effect on forest health and sustainability (Fahrig 2005). Forests in Argentina and Chile have been severely affected by progressive fragmentation and forest loss in the last decades (Aizen and Feinsinger 1994; Echeverria et al. 2006, 2008). Under a landscape ecology perspective, it has been observed that changes in patch spatial attributes by fragmentation are associated with changes in forest structure and composition at the stand level. Particularly, changes were recorded in basal area and canopy cover (Echeverria et al. 2007) and species composition (Altamirano et al. 2007; Echeverria et al. 2007). Observed changes in canopy cover as a result of human disturbances (Echeverria et al. 2007) produce variations in growth and regeneration in uneven-aged forest in Chile (Donoso 2005). These changes have relevant implications for forest management (Donoso and Nyland 2005). Silviculture measures and conservation actions should not ignore the spatial patterns imposed at the landscape level. There is little doubt that landscape ecology is making a significant contribution to forest management and biodiversity conservation.

15.5.2 Managing strategies

Natural forests around the world have been mainly managed by the following economic criteria (McComb et al. 1993; McClellan et al. 2000). In the Northern Hemisphere, most of the natural forests were transformed by silviculture into single-species stands with a regulated age structure (Oliver and Larson 1996). Forests of Argentina and Chile follow this trend (Martínez Pas-

tur et al. 2000), supported by prevailing economic interests regarding forest management decisions (Gea et al. 2004). Most of the silvicultural proposals recommend transforming the uneven-aged original structure to an even-aged managed forest via natural regeneration of the harvested stands through their own seed production (Schmidt and Urzúa 1982). The *Nothofagus* forests of Argentina and Chile have been traditionally managed through high grading cuttings or clear-cuts, and recently by shelterwood cuts (Schmidt and Urzúa 1982; Martínez Pastur et al. 2000; Gea et al. 2004; Rosenfeld et al. 2006), which significantly affects the original diversity (fungi, plants, birds, insects and mammals) (Deferrari et al. 2001; Spagarino et al. 2001; Martínez Pastur et al 2002; Ducid et al. 2005). Recently, ecological and social criteria have been elevated over economic criteria (DeBell and Curtis 1993; Mitchell and Beese 2002). For these reasons, new silvicultural methods were proposed. These new methods were designed to conserve some of the original heterogeneity of the natural old-growth forests. One of them proposes to leave 30% of the timber forests (stands with up to 40 m^3 ha^{-1} of saw-timber logs) as aggregated retention and 10-15% basal area as dispersed retention (for details see Martínez Pastur et al. 2007, 2009), which is expected to conserve the original biodiversity affected by forest management (Vergara and Schlatter 2006; Lencinas et al. 2007, 2009) (Fig. 15.4). Aggregated retention was defined as one circular patch of 60 m diameter per ha of original forest, while dispersed retention was composed of remnant trees homogeneously distributed between the aggregates. The implementation of this method was feasible at large ecological scale in Tierra del Fuego (Argentina). In this southernmost forest, the yield loss and costs increase due to the retention overstory and was compensated by the decrease in harvesting costs (Martínez Pastur et al. 2007). Furthermore, a short-term analysis showed that biodiversity ecological cycles were improved with this new method when compared to shelterwood cuts (Martínez Pastur et al. 2007; Lencinas et al. 2007, 2009). At a large scale, this method proved to be economically feasible across a gradient of site quality, producing stability in the remnant overstory and successful regeneration (Martínez Pastur et al. 2007, 2009) patterns.

Regeneration systems that include different kinds and types of retention were proposed to combine timber production interests and the consideration of other forest values (DeBell and Curtis 1993). The regeneration method with aggregated and dispersed retention maintains the same yield rates as the first cut of the shelterwood system. Contrary to shelterwood cuts, this method reduces both harvesting costs (Martínez Pastur et al. 2007) and biodiversity loss (Lencinas et al. 2007). The main disadvantage found was the loss of timber in the retained trees, caused by collateral damage while felling neighboring trees and blow-down after harvesting (Hickey et al. 2001). Nevertheless, this system helps to maintain ecosystem health, resilience, and productivity, as well as compositional, structural, and functional diversity of the managed forests (McClellan et al. 2000). Also, they produce a sustainable supply of timber

while imposing a set of complex biologically and socially acceptable management objectives, combining economic and conservation purposes (Martínez Pastur et al. 2007).

Fig. 15.4 Variable retention silvicultural system with aggregated and dispersed retention in *Nothofagus pumilio* forests in Tierra del Fuego (Argentina).

15.5.3 Management alternatives for native forests: A solution for forest sustainability?

Within a multi-scale and a more mechanistic framework from traditional sylviculture, an integrative landscape-driven research program should be envisioned to relate ecosystem processes, global changes including climate changes and socio-economic processes across different governance levels. The development of adaptive forest management strategies under climate change is a key challenge for sustainable resource management worldwide. As climate changes, societal demands for goods and services from forests are also changing. Increasing demand intensifies the competition for resources between forest industry, the energy sector and nature conservation/other protective functions and services (including biodiversity, protection from natural hazards, landscape aesthetics, recreation and tourism). A main goal for a future sustainable

forest management should be focused on the development and evaluation of different strategies that can adapt forest management practices to multiple objectives under changing environmental conditions with a particular focus on the landscape level effect.

Conservation strategies of forested landscapes must consider forest habitat quality and biodiversity value (Luque et al. 2004; Luque and Vainikainen 2008). Forest management modifies biodiversity, with the subsequent species loss (Wigley and Roberts 1997; Deferrari et al. 2001; Jalonen and Vanha-Majamaa 2001; Spagarino et al. 2001; Martínez Pastur et al. 2002). These losses are associated with changes in forest structure, microclimatic conditions and/or nutrient cycles (Reader and Bricker 1992; Lewis and Whitfield 1999; Caldentey et al. 2001). However, most of the studies only analyze biodiversity loss in timber-quality forests (Thomas et al. 1999; Quinby 2000), without considering interactions with associated sites within the same landscape (Hutchinson et al. 1999; Rosso et al. 2000; Peh et al. 2006). Usually, forested landscapes are mosaics of different site types, where timber-quality forests rarely constitute large, continuous blocks. Natural timber-quality forests mainly occupy the best quality sites, which in most cases are also the ones with high yield marketable products. On the other hand, associated non-timber-quality stands include sites that are not harvested because of being not profitable, have legal restrictions, or have special protective functions (Lencinas et al. 2008). For example, in the central zone of Tierra del Fuego (Argentina), only 64% of the landscape forest area corresponded to timber-quality stands of *Nothofagus pumilio* characterized by large trees, with a closed canopy and high tree volume. The rest was conserved as associate non-productive environments, which act as biodiversity protection areas: *Nothofagus antarctica* forests represented 11% of the landscape, border forests (2%), streamside forests (8%), forested wetlands (2%), and open places (13%) conformed by grasslands and peatlands (Lencinas et al. 2008).

15.6 Conclusions

Protected areas are just one part of the solution towards the maintenance of forest biodiversity in the region. In order to preserve the future of forest protected areas, proper management and resources are needed to conserve the values for which they were created. Nevertheless, increasing demands for forest supplies and energy will continue to set up pressures on valuable forests systems. Only with an adequate sustainable management can forest biodiversity be preserved; managing for biodiversity, water quality or natural disturbance requires a regional or landscape perspective. In addition, managers must also begin to anticipate how activities in one area might affect the physical and biotic properties of adjoining areas. The challenge is then to improve forest management and productivity while keeping the strength on biodiversity

conservation measures.

Understanding the interrelation between ecosystems and landscapes level mechanism is critical. An integrative landscape-driven research should be envisioned to relate ecosystem processes, global changes including climate changes and socio-economic processes across different governance levels. Within this integrative framework, predicting biodiversity change involves understanding not only ecology and evolution, but also the complex changes in human societies and economies. One of the most important challenges for future forest research will be to integrate research across different scales, including spatial and temporal scales within an interdisciplinary and multidisciplinary framework. The success of forest management activities are grounded in the emulation of natural disturbance patterns. Maintaining or creating particular landscape characteristics increases the likelihood that all the biological diversity associated with the landscape will be perpetuated. Taking a landscape-level approach means that planning and resource decision-making are undertaken in the context of the entire landscape, as opposed to planning for discrete parcels of land. By planning and managing at a landscape level and considering spatial and temporal aspects, both resource protection and sustainable use can be better accommodated without undue conflict or displacement.

There is a need to develop management and planning options both for landscapes that are already significantly altered, in need of either improved management or restoration and for forest landscapes, which are still relatively altered, but which are under increasing human pressures. The ability to provide such options depends on an understanding of landscapes processes and the ability to use this understanding to develop strategies, which are effective in dealing with the biophysical problems while at the same time being socially and economically acceptable. National and international support for regeneration and restoration activities is needed.

Baseline data and continuous high quality data bases are needed to plan and monitor forest management. In this chapter, most of the national and regional data we presented are from the 90's and other statistics for the region are based on FAO (2007). Subsequently, long-term data are needed to develop appropriate management options and plan for changes within climate change scenarios that will affect these native forests. Good forest inventory data at National level are proven to be very expensive and difficult to keep within political instability and short-term planning. Free and open access to biodiversity data is today a reality (http://www.gbif.org), but much work needs to be done to fulfil the data portal with good data quality for countries where they are most needed. Particularly data for forest monitoring at the right spatial and temporal scales are lacking. Integration of methods and a more intensive use of remote sensing as Lidar sensors and geo-statistics are needed. In summary, more support needs to be given to enhance collaboration and maintain long-term databases. It is essential to link good quality data with a sound institutional framework to ensure continuity and long-term collabora-

tion. In that sense, funding to create continuous high quality data should be a worldwide effort.

In the same way, as the lack of long-term spatial ecological data, the region is lacking academic programs in conservation (Mendez et al. 2007). In order to meet the forest management challenges that lie ahead, capacity-building opportunities on landscape ecology and conservation need to be implemented that encompasses different levels, audiences and contexts (Bonine et al. 2003; Brooks et al. 2006).

Focus on concrete measures in relation to policy implications and problems of implementation are another big challenge. Forest legislation in Argentina and Chile is quite advanced, but problems remain on the implementation. In the first place, an international code of ethics for logging companies operating around the world is needed. Investment in research from logging companies is also needed in the regions where they exploit most of the resources. IUFRO has an important role to play in the future supporting a framework for an international legislation in relation to timber extraction and forest management.

Despite all the progress achieved, integrative research is lacking, innovative questions are evasive or difficult to get funded. We need to reach a better understanding of the interwoven landscape mosaics to elucidate complexity and scale interdependencies mechanisms within the forest system. Landscape ecology provides an interdisciplinary approach to actually bridge the many gaps we face today to work towards the new challenges and endeavours of human social and ecological processes. This holistic approach of forest landscapes management can help to build up future research and tools towards an adaptive forest management approach to preserve forest biodiversity value while promoting the sustainable use of forests.

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